1.5 Liquefied Petroleum Gas Combustion

1.5.1 General[1]

Liquefied petroleum gas (LPG or LP-gas) consists of propane, propylene, butane, and butylenes; the product used for domestic heating is composed primarily of propane. This gas, obtained mostly from gas wells (but also, to a lesser extent, as a refinery by-product) is stored as a liquid under moderate pressures. There are three grades of LPG available as heating fuels: commercial-grade propane, engine fuel-grade propane (also known as HD-5 propane), and commercial-grade butane. In addition, there are high-purity grades of LPG available for laboratory work and for use as aerosol propellants. Specifications for the various LPG grades are available from the American Society for Testing and Materials and the Gas Processors Association. A typical heating value for commercial-grade propane and HD-5 propane is 90,500 British thermal units per gallon (Btu/gal), after vaporization; for commercial-grade butane, the value is 97,400 Btu/gal.

The largest market for LPG is the domestic/commercial market, followed by the chemical industry (where it is used as a petrochemical feedstock) and the agriculture industry. Propane is also used as an engine fuel as an alternative to gasoline and as a standby fuel for facilities that have interruptible natural gas service contracts.

1.5.2 Firing Practices[2]

The combustion processes that use LPG are very similar to those that use natural gas. Use of LPG in commercial and industrial applications may require a vaporizer to provide the burner with the proper mix of air and fuel. The burner itself will usually have different fuel injector tips as well as different fuel-to-air ratio controller settings than a natural gas burner since the LPG stoichiometric requirements are different than natural gas requirements. LPG is fired as a primary and backup fuel in small commercial and industrial boilers and space heating equipment and can be used to generate heat and process steam for industrial facilities and in most domestic appliances that typically use natural gas.

1.5.3 Emissions[1,3-5]

1.5.3.1 Criteria Pollutants -

LPG is considered a "clean" fuel because it does not produce visible emissions. However, gaseous pollutants such as nitrogen oxides (NO_x), carbon monoxide (CO), and organic compounds are produced as are small amounts of sulfur dioxide (SO_2) and particulate matter (PM). The most significant factors affecting NO_x, CO, and organic emissions are burner design, burner adjustment, boiler operating parameters, and flue gas venting. Improper design, blocking and clogging of the flue vent, and insufficient combustion air result in improper combustion and the emission of aldehydes, CO, hydrocarbons, and other organics. NO_x emissions are a function of a number of variables, including temperature, excess air, fuel and air mixing, and residence time in the combustion zone. The amount of SO_2 emitted is directly proportional to the amount of sulfur in the fuel. PM emissions are very low and result from soot, aerosols formed by condensable emitted species, or boiler scale dislodged during combustion. Emission factors for LPG combustion are presented in Table 1.5-1.

Table 1.5-1 presents emission factors on a volume basis (lb/10^3gal). To convert to an energy basis (lb/MMBtu), divide by a heating value of 91.5 MMBtu/10^3gal for propane and 102 MMBtu/10^3gal for butane.

1.5.3.2 Greenhouse Gases[6-11] -

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions are all produced during LPG combustion. Nearly all of the fuel carbon (99.5 percent) in LPG is converted to CO_2 during the combustion process. This conversion is relatively independent of firing configuration. Although the formation of CO acts to reduce CO_2 emissions, the amount of CO produced is insignificant compared to the amount of CO_2 produced. The majority of the 0.5 percent of fuel carbon not converted to CO_2 is due to incomplete combustion in the fuel stream.

Formation of N_2O during the combustion process is governed by a complex series of reactions and its formation is dependent upon many factors. Formation of N_2O is minimized when combustion temperatures are kept high (above 1475°F) and excess air is kept to a minimum (less than 1 percent).

Methane emissions are highest during periods of low-temperature combustion or incomplete combustion, such as the start-up or shut-down cycle for boilers. Typically, conditions that favor formation of N_2O also favor emissions of CH_4.

1.5.4 Controls

The only controls developed for LPG combustion are to reduce NO_x emissions. NO_x controls have been developed for firetube and watertube boilers firing propane or butane. Vendors are now guaranteeing retrofit systems to levels as low as 30 to 40 ppm (based on 3 percent oxygen). These systems use a combination of low-NO_x burners and flue gas recirculation (FGR). Some burner vendors use water or steam injection into the flame zone for NO_x reduction. This is a trimming technique which may be necessary during backup fuel periods because LPG typically has a higher NO_x-forming potential than natural gas; conventional natural gas emission control systems may not be sufficient to reduce LPG emissions to mandated levels. Also, LPG burners are more prone to sooting under the modified combustion conditions required for low NO_x emissions. The extent of allowable combustion modifications for LPG may be more limited than for natural gas.

One NO_x control system that has been demonstrated on small commercial boilers is FGR. NO_x emissions from propane combustion can be reduced by as much as 50 percent by recirculating about 16 percent of the flue gas. NO_x emission reductions of over 60 percent have been achieved with FGR and low-NO_x burners used in combination.

1.5.5 Updates Since the Fifth Edition

The Fifth Edition was released in January 1995. Revisions to this section since that date are summarized below. For further detail, consult the memoranda describing each supplement or the background report for this section.

Supplement A, February 1996

No changes.

Supplement B, October 1996

- Text was added concerning firing practices.
- The CO_2 emission factor was updated.
- Emission factors were added for N_2O and CH_4.

July 2008

The PM filterable, NOx, CO and TOC emissions factors were updated and the PM condensable and PM total emissions factors were added using the revised PM, NOx, CO and TOC emissions factors for natural gas combustion for small boilers (see July 1998 revisions to section 1.4, Natural Gas Combustion).

Table 1.5-1. EMISSION FACTORS FOR LPG COMBUSTION[a]

EMISSION FACTOR RATING: E

Pollutant	Butane Emission Factor ($lb/10^3$ gal)		Propane Emission Factor ($lb/10^3$ gal)	
	Industrial Boilers[b] (SCC 1-02-010-01)	Commercial Boilers[c] (SCC 1-03-010-01)	Industrial Boilers[b] (SCC 1-02-010-02)	Commercial Boilers[c] (SCC 1-03-010-02)
PM, Filterable [d]	0.2	0.2	0.2	0.2
PM, Condensable	0.6	0.6	0.5	0.5
PM, Total	0.8	0.8	0.7	0.7
SO_2[e]	0.09S	0.09S	0.10S	0.10S
NO_x[f]	15	15	13	13
N_2O[g]	0.9	0.9	0.9	0.9
CO_2[h,j]	14,300	14,300	12,500	12,500
CO	8.4	8.4	7.5	7.5
TOC	1.1	1.1	1.0	1.0
CH_4[k]	0.2	0.2	0.2	0.2

[a] Assumes PM, CO, and TOC emissions are the same, on a heat input basis, as for natural gas combustion. Use heat contents of 91.5 x 10^6 Btu/10^3 gallon for propane, 102 x 10^6 Btu/10^3 gallon for butane, 1020 x 10^6 Btu/10^6 scf for methane when calculating an equivalent heat input basis. For example, the equation for converting from methane's emissions factors to propane's emissions factors is as follows: lb pollutant/10^3 gallons of propane = (lb pollutant /10^6 ft^3 methane) * (91.5 x 10^6 Btu/10^3 gallons of propane) / (1020 x 10^6 Btu/10^6 scf of methane). The NO_x emission factors have been multiplied by a correction factor of 1.5, which is the approximate ratio of propane/butane NO_x emissions to natural gas NO_x emissions. To convert from lb/10^3 gal to kg/10^3 L, multiply by 0.12. SCC = Source Classification Code.

[b] Heat input capacities generally between 10 and 100 million Btu/hour.

[c] Heat input capacities generally between 0.3 and 10 million Btu/hour.

[d] Filterable particulate matter (PM) is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. For natural gas, a fuel with similar combustion characteristics, all PM is less than 10 μm in aerodynamic equivalent diameter (PM-10).

[e] S equals the sulfur content expressed in gr/100 ft^3 gas vapor. For example, if the butane sulfur content is 0.18 gr/100 ft^3, the emission factor would be (0.09 x 0.18) = 0.016 lb of SO_2/10^3 gal butane burned.

[f] Expressed as NO_2.

[g] Reference 12.

[h] Assuming 99.5% conversion of fuel carbon to CO_2.

[j] EMISSION FACTOR RATING = C.

[k] Reference 13.

References For Section 1.5

1. Written Communication from W. Butterbaugh of the National Propane Gas Association, Lisle, Illinois, to J. McSorley of the U. S. Environmental Protection Agency, Research Triangle Park, NC, August 19, 1992.

2. Emission Factor Documentation for AP-42 Section 1.5. *Liquefied Petroleum Gas Combustion.* April 1993.

3. *Air Pollutant Emission Factors*, Final Report, Contract No. CPA-22-69-119, Resources Research, Inc., Reston, VA, Durham, NC, April 1970.

4. *Nitrous Oxide Reduction With The Weishaupt Flue Gas Recirculation System*, Weishaupt Research and Development Institute, January 1987.

5. Phone communication memorandum of conversation between B. Lusher of Acurex Environmental and D. Childress of Suburban/Petrolane, Durham, NC, May 14, 1992.

6. L. P. Nelson, *et al.*, *Global Combustion Sources Of Nitrous Oxide Emissions*, Research Project 2333-4 Interim Report, Radian Corporation, Sacramento, CA, 1991.

7. R. L. Peer, *et al.*, *Characterization Of Nitrous Oxide Emission Sources*, EPA Contract No. 68-D1-0031, Research Triangle Park, NC, 1995.

8. S. D. Piccot, *et al.*, *Emissions And Cost Estimates For Globally Significant Anthropogenic Combustion Sources Of* NO_x, N_2O, CH_4, *CO, And* CO_2, EPA Contract No. 68-02-4288, Research Triangle Park, NC, 1990.

9. G. Marland and R. M. Rotty, *Carbon Dioxide Emissions From Fossil Fuels: A Procedure For Estimation And Results For 1951-1981*, DOE/NBB-0036 TR-003, Carbon Dioxide Research Division, Office of Energy Research, U.S. Department of Energy, Oak Ridge, TN, 1983.

10. G. Marland and R.M. Rotty, *Carbon Dioxide Emissions From Fossil Fuels: A Procedure For Estimation And Results For 1950-1982*, *Tellus*, 36B: 232-261.

11. *Sector-Specific Issues And Reporting Methodologies Supporting The General Guidelines For The Voluntary Reporting Of Greenhouse Gases Under Section 1605(b) Of The Energy Policy Act Of 1992,* Volume 2 of 3, DOE/PO-0028, U.S. Department of Energy, 1994.

12. A. Rosland, *Greenhouse Gas Emissions In Norway: Inventories And Estimation Methods*, Ministry of Environment, Oslo, Norway, 1993.

13. *Inventory Methods Manual For Estimating Canadian Emissions Of Greenhouse Gases*, Prepared for Environment Canada by Ortech Corporation, 1994.